SIGMA XI QUARTERLY

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THE THIRTY-FIFTH CONVENTION

It is not too early for all chapters and clubs to begin making plans to be represented at the thirty-fifth convention of our great Society which is to be held in Pittsburgh in December. It is a matter of importance in the progress of our affairs that each chapter and club should have one or more delegates at the meeting to participate in the Society's business, make recommendations, and to inform fellow representatives about chapter and club activities. Definite plans will be formulated for our semi-centennial schedule for Ithaca in June, 1936. President Parker is proud to announce on behalf of the Society at large that the thirteenth annual address given under the joint auspices of the American Association for the Advancement of Science and Sigma Xi will be given by Dr. Irving Langmuir, who has chosen as his topic "The Modern Scientific Attitude."

Chapter and club officers are asked to urge their membership to read the minutes of the thirty-fourth convention as printed in the March issue of the QUARTERLY, and the minutes of the Executive Committee as given in that issue and the June number in order to have in mind for possible discussion at some of the autumn meetings the recent transactions of the national organization.

WHO'S WHO IN THIS ISSUE

The authors of the articles we are privileged to present to our membership in this number of the QUARTERLY need no introduction to scientists anywhere in the world.

DR. WILLIS RODNEY WHITNEY is the famous director of the Research Laboratory of the General Electric Company, who has always given enthusiastic and influential support to scientific research, both industrial and theoretical.

DR. IRVING LANGMUIR, an intimate colleague of Doctor Whitney, a Nobel Prize winner, has made many important contributions to modern physics and chemistry.

PROF. GEORGE H. SHEPARD adds to his work as professor of industrial engineering and management at Purdue University a profound interest in human social problems.

We are privileged to present to twelve thousand readers three such timely articles by scientific leaders.

SIGMA XI SCIENCE, HOBBIES AND HABITS*

W. R. WHITNEY

Vice-President in charge of Research, General Electric Company

I want to say something to the boys back there in the corner—the new members of Sigma Xi. The older people don't concern me so much. I couldn't change their minds if I tried, and I'm interested in putting over an idea. Possibly I can say something that may help some one young man to have a good time through life.

I think that the existence of Sigma Xi may be due to Bacon. I know that I agreed to talk my turtle hobby, and I'll try to get over this dry part of the talk in a moment, so that we can think turtle.

Francis Bacon was apparently the first man completely to visualize the possibilities of deliberately producing new environment, of cutting away from a lot of old, false traditions, forgetting "idols of the market-place," which are just words used by people who depend on imposed environments. He determined to do all he could to get people to change their ideas and learn to alter their environments; actually to alter their habits of mind and thus add to their utilities, so to speak. He said he "had never met any person disposed to apply his mind to similar thoughts." He saw that man differed from all other animals in possessing the more or less undeveloped power of systematically altering things, of learning new matter and of producing unusual environments of broad significance. He insisted that we ought to study our material possibilities. He thought, rightly, that man could learn by experiments deliberately planned (trial balloons in a stratosphere), and could use the new knowledge as no other animal had ever thought of doing. Of course, lower animals can alter their environments, and perhaps, in a sense, each individual animal or plant is trying to do it all the time. That is life. But my idea is that they respond as best they can, and variously, to the external changes which the world seems to impose upon them. They do not plan and build their own.

And now I will introduce my turtles.

In the Peabody Museum at Yale there is the fossil skeleton of a two-ton water turtle which probably lived here about five hundred million years ago. I may be a bit off as to dates. But I'll assume, and welcome corrections, that man has been here about one million years, or one five-hundredths as long as the water turtle. The *land* turtle was a later product which probably was developed from the water turtle by changed environment. The waters, in fact, receded, and left lots of water turtles stranded, or half stranded. Most of these, forced to research, died, but two or three got through and established the intelligent, deliberate land turtle. They had not altered their environment in order to learn new stuff, but the result was the same as though they had. On land they tried swimming, and so learned to walk. They looked for sea-food and found land vegetation galore. They met all sorts of new conditions and

* Address to the initiates and members of the Union Chapter.

so built a superior brain. In other words, the new style brain of the land turtle now included a cortex filled with experiences which are fixed in the cortex as a network of electrically conducting nerves suitably interconnected. They serve as control switchboards of thought and power. Our own brains are built on the same plan. But we can apparently build them ourselves, just as a telephone company, entering new fields, erects supports and string wires which, in turn, connect to countless local and long-distance thought and power stations. It is this cortex which serves us as our center of imagination, of inventive ability—as a planning device. It enables us to deliberate on our reactions, to postpone actions, so that these are not merely sudden reflex muscular activities.

The water turtle is said to have no cerebral cortex, and that is probably why he will quickly crawl to the edge of any shelf, however high, and jump over. To him, everything is either log or water. The land turtle doesn't jump under such conditions, and even if blindfolded, will stop to scratch off the bandage before he will move, and then he declines to take the fall.

So I assume that the land turtle may have been accumulating the experiences of changing environment for, say, 250 million years; anyway, long enough to have also got into the fossil class with his little, early cortex.

And now I come to Bacon again. He is in the line of animals with growing cortex, but he had designs destined to deliberately make changes in environment, to try things not absolutely forced upon us from outside. He didn't believe in merely thinking, doing and saying only what had been thought, done or said before. Discussions over the number of angels that could dance on a pin-point did not please him. Had anyone ever tried the experiment? What was an angel, anyway? Had anyone ever even seen one? If not, why not start learning what might be possible? So he started preaching experimentation. I think he found it a terrible job. It was in Queen Elizabeth's reign, and he began to write books on this idea which seemed to him more important than his other work as Keeper of the Royal Seal, or Treasurer of the greatest empire of the world. His books are a lesson to me. He tried to publish several, mostly on the importance of learning new truth, methodically, by simple, organized processes. Two of his best books we know now as "The Advancement of Learning" and "The Novum Organum." No one has told me this, but I think he saw that nobody cared about his foresighted views. People were interested far more in eating and drinking (with any number at table except thirteen), and they were afraid to start anything new (particularly on Fridays).

There had already been more written than anyone cared to read, so why follow Bacon's wild schemes? Just remember that all this was at a time when people didn't even know that the heat of a freshly killed animal was the same kind as that you find in a warm stove. I just about know that he disgustedly quit his difficult writing and said to himself, "I've got to write some sort of a child's story for such people." So he wrote the sailors' shipwreck yarn called "The New Atlantis." People had heard the Greek stories of Atlantis (the sunken island). So he had his sailors discover a new Atlantis. There they

found an organization which suggests Sigma Xi. It was called "Solomon's House." Here the members met to discuss all they learned by traveling about the world, and here they added to knowledge, by research, whatever they could in any way. But, unlike Sigma Xi, they were loath to tell others of their advances. Now Soloman's house got to be a real thing in the minds of some English people, though for years it was not even anything to aim for but rather something to shoot at. However, it stuck in the fertile if fixed minds of a lot of good Englishmen.

In the story of Soloman's house, the visiting sailors had learned about many new discoveries which the scheme had produced—things which were quite unknown to the rest of the world at the time. They learned that boats could be driven by something other than sails or oars—by what we now call steam; that there were even boats which would proceed under water. Wagons were not necessarily horse-driven, but went by mysterious power—we say "gas." A certain amount of flying was practiced, in imitation of birds, and countless therapeutic discoveries, such as synthetic salt baths, had been perfected. In this yarn Bacon invented, I think, twenty-two different, unheard of devices, just to show what might come out of experimental research to benefit the people. He didn't begin to exhaust the possibilities, of course, but it is strange to us chemists that the only one he depicted which has not already been accomplished is the filtering of sea water to get potable water. A man who could get twenty-one out of twenty-two forecasts correct must have been worth listening to. Maybe his pure scientific efforts failed for a time, but his story of the devices of Soloman's house was like seed, and these fell in a few fertile places. They didn't have radio in Soloman's House, nor x-rays, nor decaying elements; no cosmic rays, no rare gases, no stratosphere. But Bacon prophesied just enough to start things moving.

I want to mention a few Englishmen in whose fertile minds Bacon's seed was producing an effect twenty years after his death, which occurred in 1626.

You have all heard of John Evelyn's *Journal* and of Samuel Pepys' diary. You know Robert Boyle by his gas laws. Sir Christopher Wren, the architect of St. Paul's, is known to you. Evelyn's letters to Boyle in '57 and '59 refer to Bacon's "Soloman's House," and suggest forming such a scientific group, though on a modest scale. This was finally done, at Gresham College, and dubbed the Invisible College. The members tried all sorts of experiments and reported at meetings. Evelyn's book on trees, "Sylva," was one of his contributions. At a meeting in 1660 Wren gave a lecture. Pepys became a member in 1665, and he tells in his diary of some interesting experiments he witnessed. In 1661 King Charles joined the Society, which had limited its numbers to fifty-five. The next year a charter was issued to them as the Royal Society. Thus the first great scientific society was due to Bacon's efforts. It still exists, and has been responsible for many others. Later, our own Benjamin Thomson, who became Count Rumford, helped the Royal Society to establish the Royal Institution, where the highest class of scientific research work has been continued down to our day. Here Faraday was "produced," one might say, by

Davy, who was president, and Faraday, too, later became president. Professor Bragg is now the president. Our Benjamin Franklin was a member of the Royal Society, and it is probable that he established our oldest scientific society, The Philosophical Society, because of the earlier British prototype. So we continue to see the light of Bacon's lamp.

When Eliot, the late president of Harvard, was a young man, he was all prepared to take a commercial position in a Boston business house, but, influenced by his reading of Bacon, decided, at the last moment, to take up science instead. I tell you all this perhaps to justify my fancy that the Sigma Xi Society of which you are now members owes its existence to Francis Bacon.

Tonight, just before I came to this dinner, I took a walk to see if I could find a special turtle message to bring you. I found three of my old turtle friends, which I took back to the house. There I compared them with the records in my turtle books. You see, I enjoy a real business of making turtles an important matter. I record data not to test some theory or a notion, but to see if I can get facts which may call for a theory, or disclose something new. One of these turtles had "W" carved on its back, together with the numbers '15, '22, '25, '26, '27, '28, '29, '30 and '32. My books showed where I had found her in each one of those years. They also showed her dimensions and exact weight at each period. I measured, weighed, and recorded her anew, added '34 to her shell, and set her free again. This was done not where I found her, but at the same spot where I launch all turtles I find, which is a quarter mile from her home. I know now that she will go back to her home. I also know other habits. I know she travels from her winter home, about half a mile, and regularly, in early June, lays nine eggs in the sand of a certain hillside. She also travels a bit during the summer, usually in shady places, but in the past nineteen years she has probably never been a mile from home. Now what good is all that? I don't have to tell you. It is a personal affair between me and the turtles. But it is forever giving me new interests. I have a feeling that all knowledge is interconnected, and each part fits together with a whole lot of other parts through delicate contacts which it is fun to appreciate.

Here's an illustration of contacts: I recently attended a Sigma Xi meeting at Troy, where Doctor Berg introduced Doctor Crozier, of Harvard, who talked psychology and geotropism. I happened to know a tiny bit about geotropism because I've read about heliotropism. He was telling of his hope of measuring quantitatively psychological phenomena as disclosed by well-bred white rats. He reported on the geotropism of the rats as affected by their heredity, and of the angles they prefer when climbing a certain wire screen. I was doubly interested, for here was someone trying to obtain measurable and repeatable results of heredity and environment on the psychology of the rat. I don't call psychology a science yet, because so little quantitative work has been done in it, but some of you young men may help it to become a science by making measurable mental experiments. Numerical data are necessary for any science. I don't say that mathematics leads or produces science, but that it is an essential part of it. At Professor Crozier's lecture I realized that I had studied turtle

geotropism without knowing it. Several times, just for fun, I had taken nine one-day old land turtles and placed them on the lawn, to see what their ideas of departing might be. We think of turtles as being slow and indeterminate. But in from five to eight minutes all nine turtles had sought and found a downgrade. They had never seen anything before outside of the flatness of a bit of sand, and the sunlight overhead. But now they were fast getting away by what we call their geotropism. Ants and flies, when they walk, will usually climb upward; the baby land turtles prefer a downward direction. Now we in our wisdom can give the proper explanation from the data. It is a form of Darwin theory. These land turtles, all born in late fall, might freeze the first night if they could not find the warm mud beneath some water which they have never even heard about. They know exactly what to do that first day, and they all do it in quick tempo. We call that their psychological tropism. The old turtles have a much more complex tropism. Back in 1925 I placed eleven old land turtles in a row and took movie pictures of them. They moved slowly but very deliberately. I noticed that No. 1 moved uphill, and, say, No. 2, east, and No. 3, west, etc. So I started them at scratch again and found a definite new turtle tropism. Each had his or her preferred direction, regardless of slope. Now a lot of additional research work convinces me that each mature turtle has found one particular spot it likes to live in. It has a home tropism. This is perhaps relatively stronger than man's, for the turtle never goes more than a mile from home.

Now remember that we are talking about turtles and tropisms, or habits, and psychology, and I have been looking at Francis Bacon as only about as far from the land turtle psychologically as the land turtle is from the water turtle. You've been told, "Sow an act, reap a habit; sow a habit, reap a character; sow a character, reap a destiny." When psychology is a real science that will be its charter, and verifiable numbers will be attached to each paragraph. There will be a lot written about sowing new acts.

I'll tell you one more apparently irrelevant thing. I spent a few days at Yale last week. There I met two widely different kinds of people. Call them the entirely dissatisfied and the uncritical unsatisfied. One young and inquiring group quite properly asked, "What's the good of anything?" Isn't a monkey an excellency? He has all he needs and seems supremely happy. That was the view discussed years ago in a French novel, "Mon Oncle Benjamin," by Claude Tillier. Uncle Benjamin thought the monkey had the better life—no work, plenty of food and play. But I think he didn't watch the monkeys carefully enough. They are frequently monkeying—even researching. Give them any chance to learn something new and they'll take it. I read this week that guards had to stop visitors removing their false teeth in front of certain monkeys, because the monkeys tried so hard to do it that they hurt themselves. Judging from turtles, monkeys and man, we may assume that success in living is not based on wealth nor even apparent happiness. But it might be based on growing cortex. I think it is safe to say that the more the cerebral cortex is developed, the better the animal and the greater the success of the experiment. Of

course, that is why we have developed the habit we call a university. A visiting professor (not a Yale man), possibly drawing me out for the fun of the youngsters, said, "All these new products of science seem to cause so much suffering. Are they justified? Think, for example, of the old village blacksmith who has now been starved or put out of business by the automobile. How can you justify such suffering?" I asked for data or numbers, but he couldn't exactly name one such actual sufferer. So I asked if he thought a man suffered because he no longer had to work before a hot fire all day fixing red-hot shoes against the smelly, burning hoofs of frightened horses. It might be fair to ask the blacksmith, but not the remote poet, with his poetic license. Today you ride past countless fine gas stations, more than enough to take care of all the village blacksmiths. Less animal effort is required of the attendants, but there is more chance for cortical if not muscular growth. My experience checks this. The gas stations seem to improve as the cortex of the attendants grows. Not long ago they learned to wipe my windshield, not so long afterward they learned to look out for my oil and water and fix my lamps, and then one day one said, "Don't you want credit for your gasoline and pay monthly?" Even automobiles have helped develop new cortex. The morning after this Yale talk, one of the students brought me the current *New York Times*, and in it was Doctor Millikan's answer to the same question in about the same words. So I clipped it and sent it to my inquisitor.

But now for a final item on acts, habits, cortex and psychology. I met two fine research men at Yale, Messrs. Harrison and Schotté—uncritical, unsatisfied, and active. They don't talk as loud as I do, but they work with salamanders, frogs, toads, etc., and particularly with the eggs. With eggs you might think habits were simple. There is a particular stage in the development of the eggs, when they first begin to change from round to oblong. They called this stage No. 15. I think there are about thirty stages in all. At stage 15 they can predict that a front right leg will develop at a certain spot, for example. With microscopic tools made out of a baby's hair and of very fine glass fibers, they cut out a bit of treetoad's egg where the leg is expected, and they exchange it for a similar tiny speck from the corresponding part of a salamander's egg. Then the big salamander develops a small treetoad's front leg, and when the treetoad wakes up he has a larger salamander's leg where he expected his customary kind. Now that is bad enough, for I can't see how the muscle and bone connections can fit, and when it comes to the wiring diagram of the nerves I'm all at sea. But this is only part of the experiments, which show that the habit of a tiny speck of protoplasm may persist in spite of a considerably changed environment. Such experiments will supply facts for the psychologist of the future.

Think about this additional experiment.

They take a strip from the putative, or future, abdomen of a frog and substitute it for a bit on the head-front of the salamander, at egg stage 15. Now will the stomach-strip insist on growing abdomen over the face of the

(*please turn to page 91*)

SCIENCE AS A GUIDE IN LIFE*

IRVING LANGMUIR

The striking increase in knowledge of the physical world and the technical advances that have resulted from the progress of science have led to a rather widespread belief that the methods of science should be capable of solving most human problems.

The advertisements of our popular weeklies show how powerful is the appeal of the laboratory-tested antiseptic. Stock market forecasts appear to have a commercial value measured by the extent to which they are based on scientific methods.

The very phrase "brain trust" is evidence of the popular faith that science may ultimately cure all evils. Yet, of course, as we see from the frequent contemptuous references to the brain trust, there does exist a wide divergence of opinion as to the value of science and of scientists.

Let us try to analyze the characteristics of the methods that have usually been employed by scientists in attacking their problems.

An important part of a scientific investigation often lies in the recognition and the formulation of the problem and in the working out of a definite plan of attack. By the aid of imagination, tentative suppositions or hypotheses are made which suggest the procedure to be followed. There must be a deliberate limitation of the field to be covered. To avoid undesirable complications the scientists must select the factors or conditions that are likely to be important and decide which ones are so unimportant that they may be neglected. For example, in the study of a swinging pendulum the conditions should be so chosen that the results depend only on the force of gravity and on the structure of the pendulum. The problem would be enormously more complicated if the experiment were performed on a moving train.

The next step, and the one that is particularly characteristic of modern scientific research, involves the collection of experimental or observational data. In the experimental method the conditions are deliberately changed in a variety of ways and the results are noted. Much scientific work, however, has to be carried on in fields where such experimentation is impossible. For example, in astronomy we can merely observe the motions of the heavenly bodies; we cannot alter them in order to study the effects of such changes. But by getting a large amount of such observational data, particularly if they can be recorded with high precision, results may frequently be obtained which are just as significant as if experimentation were possible.

In carrying out these experiments, the scientist has learned, through sad experiences, to avoid errors which originate from his own psychology or emotional reactions. He must not favor those results which accord with his wishes or preconceived ideas. In every stage of the development of science, numerous publications have appeared announcing alleged new discoveries which, on fur-

* Address given at Union College Commencement, June, 1934.

ther investigation, are found to be wholly without foundation. Such errors result primarily from wishful thinking. A large fraction of the scientific announcements that appear in the daily press are of this type.

Having acquired a sufficient amount of experimental or observational data, the scientist then usually proceeds to develop a theory or an explanation of the phenomena he has observed. If this is done successfully, the solution or goal of the investigation is considered to have been reached.

A satisfactory theory should make possible the prediction of new relationships or the forecasting of the results of experiments somewhat different from those already performed. The scientist endeavors to make as many such predictions as possible and then proceeds to test the validity of these by further experimentation or by the collection of additional observational data. The value of a theory lies primarily in this ability to predict the results of experiment.

All of the steps which I have enumerated as characterizing scientific methods are not necessarily present in every investigation. Still the outline that I have given may be considered typical and will at least serve for an analysis of the present value of scientific method in human affairs.

This procedure which characterizes the scientific method has been evolved by the method of trial and error. Its merit lies in the fact that it so often succeeds in enabling us to predict and to correlate events, thus leading us to new discoveries and simplifying our outlook.

The adoption of such a procedure is by no means a cure-all for avoiding fallacious conclusions. The scientist as much as anyone else requires sound judgment and common sense and needs to use the utmost care and conscientiousness to avoid the pitfalls towards which he is constantly tempted by wishful thinking.

If the development of a theory or explanation is the main goal of science, it will pay us to examine somewhat closely the nature of these theories. It is often thought that the aim of science is to seek truth. The modern scientist usually feels that he doesn't know what truth is—he has no accurate definition of it. The value of his explanations and theories is measured by their usefulness.

Prior to the development of the electromagnetic theory of light by Maxwell by which he laid the foundation for the understanding of both radio waves and x-rays, physicists for years had devoted a large part of their effort to a study of the theory of elasticity: for example, the bending or twisting of rods of any solid material. Maxwell was able to develop a theory of the phenomena of light by tracing a parallelism between the propagation of elastic waves in solids and the propagation of light through space. He thus explained light in terms of the hypothetical properties of an elastic medium called the ether which was supposed to fill all space. All electric and magnetic phenomena were thus explained in terms of elasticity which was more familiar to physicists. This was regarded as such a satisfactory theory that Lord Kelvin, for example, believed the existence of the ether to be one of the most firmly established scientific facts.

Physicists of the present generation have relatively little interest in the theory of elasticity, but are extremely familiar with electric and magnetic phenomena. So today we find the situation reversed: the forces between atoms which are responsible for elasticity are explained in electric and magnetic terms. The question of the existence or non-existence of the ether has ceased to be important.

Our theories consist essentially in the setting up of a model which has properties analogous to the phenomena which we have observed. For example, Bohr, taking into consideration certain properties of hydrogen atoms, proposed a model for these atoms which consisted of an electron revolving in an orbit about a nucleus. The energy changes that would take place in this model, according to calculation, were found to be identical with those that were observed for hydrogen atoms. The theory was thus useful and served to explain the properties of hydrogen.

Since any such model is an abstraction formed for a definite purpose, it is necessarily incomplete and therefore the model must never be confused with the physical phenomena which it represents. We should therefore never ask whether the model represents reality. It is sufficient to say that in certain respects it corresponds to reality. For example, although the equations which Bohr derived from a consideration of his model are still valid, we have today quite other explanations of the behavior of these atoms. The original Bohr model has lost its usefulness.

Even the atomic theory of matter which is universally accepted today is really a kind of model, in which chemical compounds are conceived of as being made up of definite arrangements of atoms, to which we assign suitable properties. Mendel's Law of Inheritance, as modified by the more recent concept of chromosomes and genes, is a kind of Atomic Theory of Heredity. This theory too is a model which is designed to correspond to known observational facts.

Most of the laws of physics are stated in mathematical terms. But a mathematical equation itself is nothing more than a kind of model. We establish, or assume, a correspondence between observable quantities and the symbols of an equation, and then, after a mathematical transformation, obtain a new relation or equation. If we can establish a similar correspondence between the symbols of the new equation and observational data obtained after an experiment has been performed, we have demonstrated the power of the mathematical theory to predict events. It thus becomes a useful theory.

Up to the beginning of the present century the results obtained by the application of these scientific methods to the study of natural phenomena, possessed certain definite characteristics which differ in many respects from some of the fundamental theories that have been evolved in more recent years. In fact a revolution has taken place in the attitude of the scientist toward his theories. We usually refer to the physics of the old type as *classical physics*. The results of *classical physics* were expressed in terms of *natural laws* which were thought of as immutable relations between cause and effect. For example,

if the positions, the velocities and the masses of the heavenly bodies are given it is possible to predict with nearly unlimited accuracy the positions of the bodies at any future time. Such an idea of causation has long been firmly imbedded in our minds and in our language, even before science had become of importance. The teachings of classical science made causation a universal dogma.

From this viewpoint the proper field for science was unlimited. Given sufficient knowledge all natural phenomena, and by inference all human affairs, could be predicted with certainty. Ampere, for example, over a century ago, stated that if given the position and velocities of all the atoms in the universe, it should be possible theoretically to determine the whole future history of the universe. Many philosophers, of course, pointed out that such a statement was meaningless because there is no possibility of ever obtaining such a detailed knowledge of the universe as Ampere's postulate would require.

The revolution in physical thought which has characterized the present century started in 1903 with Einstein's relativity theory. Far more important than this theory itself is the new method of thinking which was introduced by Einstein. A particularly keen analysis of these new trends in thought has been given by Professor Bridgman in his book "The Logic of Modern Physics." The analysis may be summarized by the statement that "Concepts have meaning only in so far as they can be defined in terms of operations or specifications." This may sound rather abstruse, but it is really quite simple. By concept, of course, we mean any idea or set of ideas which may be expressed by a word or group of words. Let me illustrate. The concepts of space or time which appear so fundamental to us, have meaning only in so far as we are able to agree upon methods of measuring space and time by definite experiments or observations. This is just what Einstein pointed out in his relativity theory, but Bridgman wants us to go further and apply it to all scientific and even non-scientific concepts. The word atom thus stands for the sum total of our knowledge which has led us to choose the atom as a useful concept.

Although few scientists have consciously recognized the importance of defining concepts in terms of operations, nearly the whole of modern theoretical physics has been based on just this point of view.

The progress of science depends largely upon defining more precisely than before, the set of operations that are adopted as representing a given concept. The scientist has always made efforts at precise definitions. When the scientist uses the terms, *atom, force, chemical element,* he means something much more definite than when the layman uses these same terms, and it is only by these relatively exact definitions that he has been able to formulate natural laws in such a useful way.

From the new point of view every word and concept is necessarily somewhat indefinite or fuzzy in character. We shall see that this becomes particularly important when we attempt to apply scientific principles to everyday life. It is just this fact that involves a severe limitation in the applicability of science.

Another factor which has profound effect on physical thought is the increasing importance of what is known as the quantum theory. It is in many respects equivalent to the more popular Uncertainty Principle. According to this principle it is fundamentally impossible to measure accurately both the velocity and the position of any single particle. Thus one cannot predict with certainty the future movement of a single particle, so that the basis for Ampere's estimate for the scope of science has vanished.

Bohr has pointed out, even long before the Uncertainty Principle was proposed, that the uncertainties introduced by the quantum theory are dependent on the fact that any scientific *observation* necessarily modifies that which is being observed and therefore the mere fact of observation precludes, in any absolute sense, the possibility of accurately forecasting the future.

The net result of the new definition of concepts and of the Uncertainty Principle has been almost to wipe out the dogma of causation.

How is it then that classical physics led to such definite, clean-cut laws? The modern answer is that the classical physicist chose as the subjects of his studies those natural phenomena which depend on the behavior of enormous numbers of atoms rather than upon individual atoms, so that the effect of the individual atom was averaged out and became imperceptible. We have many familiar examples of this kind. The deaths of *individual* human beings cannot be predicted, but the average death rate in any age group can be predicted with great certainty.

There are, on the other hand, phenomena in which large effects arise from small beginnings. A crystal grows from a sub-microscopic nucleus; a thunderstorm must start from a few minute drops of water condensing from an originally clear atmosphere. Particularly in the phenomena of life we see how every individual plant and animal grows from a minute seed. Events of enormous human importance are often the outgrowth of trivial factors. A scientist, for example, may become interested in details shown by a photograph of the path taken by a single atom in moving through gases, and by so doing, may be delayed in leaving his laboratory so that he avoids an otherwise fatal automobile accident. The behavior of a single atom, which, according to the uncertainty principle, is unpredictable, can thus make the difference between life and death for a human being.

Individual cosmic rays, inherently unpredictable, may produce mutations in germ cells and profoundly modify the hereditary makeup of human beings.

A fundamental difference between modern physics and classical physics is that it is nowadays the fashion to investigate such individual elementary phenomena.

The physicist has thus come to realize that there is no relation between cause and effect in any absolute sense. Nevertheless, in a practical sense our usual ideas of cause and effect remain unmodified when we are dealing with certain classes of phenomena in which the *probable* behavior of individual atoms suffices to determine the behavior of the aggregate. On the other hand, in another class of phenomena, which are the outgrowth of individual atomic processes, no

definite relation between cause and effect can be detected. The scientist may, however, determine with great precision what the probability is that a given elementary phenomenon will occur.

The recognition of this limitation in the idea of causality is destined to have a profound effect on our habits of thought. The science of logic itself is involved in these changes. Two of the fundamental postulates of logic are known as the Law of Uniformity of Nature, and the Law of the Excluded Middle. As often used, the first of these laws is practically equivalent to the postulate of cause and effect in nature. The second law, which may be unfamiliar to you by the name that I have given, is simply the familiar postulate that a given proposition must be either true or false.

We know the difficult position into which a witness is often forced by a shrewd lawyer who demands a yes or no answer. Thirty years ago it was common to propose the serious question, "Why is a mouse when it spins," and the answer was supposed to be, "Because, the higher the fewer." Is this answer true or false?

Logic has usually tried to avoid such situations by precise definitions of the terms used in the proposition. We now see, however, that there is always a certain amount of fuzziness inherent in any concept. So in principle, at least, the Law of the Excluded Middle has to be given up. This is being done to some extent even in the field of rigorous mathematics, but in much of modern physics this Law of the Excluded Middle is wholly out-of-date. Take, for example, the statement "Atoms are indestructible." Is this true or false? The answer depends on what aspect of atoms is being considered. To the chemist the statement is just as true as it ever was, but the physicist, studying radioactive changes, now realizes that there are conditions not previously known which can lead to a destruction of the atom.

It is easy to see that these changes that have taken place recently in scientific thought have a profound bearing on the question of the applicability of scientific reasoning in human affairs. For example, let us consider the bearing of science on social problems, such as economics and ethics.

It has usually been the aim of those who wish to apply scientific reasoning to the study of an economic problem, to determine the cause of any given economic condition. For example, it has been the desire to understand the cause of the recent depression. It is also desired to understand the effects that would be produced by any change in our present economic set-up and thus be able to plan, as in the New Deal, a system which would avoid such economic disturbances. To what extent can the methods I have outlined as being those of science be applied to such a problem? Are we justified, for example, in attempting to find a cause for the depression?

Coming back to the operational definition of concepts, we must ask what we mean by *cause* as applied to a depression. The usual operational meaning of this word is something as follows: It is a common experience in scientific investigation, particularly in the limited field selected by the classical physicist, that if a given set of physical conditions are brought about repeatedly at dif-

ferent times, the same result is found to occur in each case. Except in so far as it is possible to repeat the experiment and prove that the same result follows, it becomes impossible to give a definite meaning to the word cause.

In the case of a depression, we thus logically need to produce, or at least to observe, a given set of possible antecedent conditions, which may conceivably lead to a depression, and to see whether or not they are invariably followed by a depression.

We are immediately confronted with the difficulty that we cannot produce experimental depressions, nor have we a sufficient amount of observational data on historical depressions to enable us by statistical means to unravel the enormous number of factors that are more or less equally important.

No two depressions are in any sense identical. Those who attempt to apply the scientific method are therefore compelled to select, more or less arbitrarily, certain factors which they consider to be important. No two people in general will agree on such a selection; in fact, wishful thinking is given almost free rein in a problem of this kind. The complexity of the problem is so great and the amount of available data so meager that the value of the scientific method almost wholly disappears.

There are two points that I want to make—one is that the phrase "cause of a depression" has practically no meaning, and second, that since a depression depends upon many factors which grow from small beginnings, there is no scientific reason for believing that there *should be* any definite relation between cause and effect as applied to a depression.

Does this mean that we should give up the attempt to think clearly on social questions? I think not. We are still justified in applying common sense and good judgment, but let us not delude ourselves into thinking that we can apply the methods of science with the same certainty of useful results as have been obtained in the physical sciences.

We must not expect that the so-called law of "supply and demand" has any deeper meaning than that given by common sense. In many popular articles on economics, assertions are made which are said to be justified by the law of supply and demand. Neither supply nor demand are adequately defined and it is not at all clear what is the exact relation between them and under what conditions this relation is fulfilled. The contrast in definiteness between such a vague law as this and such a physical law as the conservation of energy is overwhelmingly great. It is hardly fair to speak of a science of economics if its results lead to laws of this kind.

It is, of course, quite possible to develop a science of economics constructed by logical processes from certain postulates just as is done in the science of geometry. For example, it is possible to start out with a hypothetical Economic Man having perfectly definite characteristics. The relation of such an economic science, however, to human affairs is highly problematical.

Within the last few years we have learned how varied, and for the most part, how futile are the recommendations of economists. Not only can they not forecast the future in any useful way, but they cannot determine the causes

of past or present events. The dire predictions of calamity which would follow our going off the gold standard are forgotten now that we are well off that standard. The president of one of our largest banks told me, in March, 1933, that in his opinion the *one outstanding cause* of the bank holiday was the fact that the government had required the publication of the names of those banks which had received government loans. I have never since been able to find anyone who has agreed with this conclusion.

Although much is written of the business cycle, there are many evidences that the rise and fall of any of our economic indexes is not much more regular than the rise and fall of gains which result from the successive tosses of a coin.

The blind faith in causation is the main source of most of the heated discussions on economic questions. A prominent editorial writer of one of our leading newspapers was led recently to vigorous denunciation of the plowing under of the new cotton crop because he believed "that the destruction of wealth cannot produce wealth." He refers to this as though it were some great natural law. But where has such a law been proved? It appears, of course, an absurdity to produce wealth by destroying it, but we live in an absurd world in which the population has the capacity and the ability to produce enough commodities to sustain a high standard of living, yet because of unemployment there does not exist the purchasing power to permit its realization. Surely there is no natural law which proves that the destruction of a certain fraction of our wheat supply could not raise the total value of the remaining wheat sufficiently to offset the loss involved.

The sponsors of the New Deal claim that they value the experimental method and that they are ready to change their plans when the results of the experiments indicate that changes are needed. At the same time they go ahead to introduce innumerable changes in our economic order. Thus when prosperity returns, no one is going to be able to say whether it can be credited to the New Deal or not.

Scientific experience should suggest to the originators of the New Deal that if useful results are to be obtained by experimentation, experiments should be confined to the alteration of a few important factors.

Our capitalist system up to 1929 was really working remarkably well. It was leading to an increasingly high standard of living and to rapid material progress. Its most important defect, I believe, was its *instability* which resulted largely from over-confidence followed by a reaction in which the psychological influences of unemployment accelerated a loss of confidence. I believe it would have been preferable, rather than to adopt the many complications of the New Deal, to have concentrated on a definite policy of reducing unemployment by the restriction of hours of labor to the point where a sufficient *scarcity of labor* would develop to bring about increased wages and therefore increased purchasing power. Flexibility could be maintained by a gradual adjustment of the maximum hours of labor dependent on the amount of unemployment existing at any time. Most of the benefits of the capitalistic system under which we have been living could thus probably be retained. At any rate, by con-

centrating on some one factor, it should have been possible to determine, with a reasonable degree of probability, whether the change was beneficial.

Man is often thought of as being a rational being. This implies that his powers of reasoning are an important part of his makeup. I think we must recognize that an overwhelming fraction of all the decisions that men must make cannot be based on pure reasoning. Reason is too slow, too limited in its scope, to be called upon very frequently. The numerous small decisions which must be made by every man each day of his life must be made quickly. They are made on the basis of common sense, experience, good judgment. These methods are far better adapted to the complexities of our lives than are the awkward processes of reasoning or the laborious processes of scientific investigations.

Of course, I would not have you go away with the impression that I believe that the application of logic and reason to human affairs is not of great value. It needs, however, to be tempered by experience and by a conscious effort to avoid wishful thinking. The test of its conclusions must rest on experimentation and observation.

Sir James Frazer's fascinating book, "The Golden Bough," gives us a marvelous picture of the growth of magic, superstitions and religions from the earliest times. It is interesting to note how frequently that what we would now regard as superstitious beliefs, rested upon rather definite reasoning. Frazer points out that most of these beliefs were based upon such general principles as "like produces like," or "things that are similar are identical." It is interesting to note that a very moderate amount of experimentation would have demonstrated the falsity of these superstitions. Of course, today we still suffer from the same lack of application of the scientific method. Perhaps the most striking demonstration that can be given is that in our largest hotels and office buildings there is usually no floor marked "13."

As an illustration of the extent to which even scientists still adhere to such a principle as "like produces like," we have the still rather widespread belief of the Inheritance of Acquired Characteristics, although there never appears to have been clear-cut evidence in favor of this belief.

The belief in immortality has frequently been justified by the argument that "Soul is a substance—substances are indestructible." Bertram Russell says that this argument in a more or less disguised form exists in many philosophies.

Questions of human ethics appear even more difficult than those of economics. We certainly cannot always say that an action must be either right or wrong. The operational definition of right and wrong presents overwhelming difficulties, and therefore the meaning of these terms is necessarily vague. Most individuals, however, still think that they are able to decide what to do by their knowledge of what is right or wrong. An established habit of doing what is believed to be the right thing is of enormous benefit to mankind. It enables us to make quick decisions and experience tells us that in the long run we profit by decisions of this type. It is much simpler to tell the "truth"

than it is to reason out whether or not it might not, on the whole, be desirable to tell a lie.

The value of a knowledge of science in human affairs seems to me to lie mainly in the molding influence that it may have upon our common sense and our intuitions. It enables us to form deliberately certain mental habits which are useful even in emergencies. *Modern* science should have a great humanizing effect by making us less dogmatic and more tolerant of the opinions of others. Believing less rigorously than before in the relation of cause and effect, we become less ready to feel that some one must be personally responsible for every undesired occurrence that affects us.

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salamander, or will the habit of the salamander, of having a face of his own, predominate, and, if so, whose face? Well, the result is the salamander grows a mouth out of the new frog-tissue, but it is a frog's mouth, not stomach cover, so there is some super-controlling organizer, apparently in the head, which decides in such cases. They say that one German has suggested that this organizer is really a chemical compound, "glycogen." This seems too sudden for me. But the point of it all is that we have wonderful opportunities of chasing new things back to simple facts and thereby having a lot of fun. This, the new work and the fun, are all properties and peculiarities of the individual cortex.

ORGANIZATION OF THE FAMILY

GEORGE H. SHEPARD

Professor of Industrial Engineering and Management, Purdue University

Organization is of primary importance to the writer as an industrial engineer. I have, therefore, spent considerable effort on the study of the evolution of organization, and began with the family as the simplest and oldest unit of human organization.

As the family is of general human interest, a discussion of the evolution of its organization may be worth consideration by members of Sigma Xi outside of my own specialty.

Organization cannot be judged solely by success or failure. An excellent organization may have failed because of adverse circumstances, and favorable circumstances may have brought success to a defective organization.

By what tests then, can the merits of an organization be judged?

Human affairs always require foresight and ability. Therefore, organization must:

Provide the means to bring to positions of power men of sufficient ability; and

Must be a tool in their hands for the achievement of ideals; that is, organization must confer power upon them.

To this aspect of the matter, the complement is, that the mass of society must be controlled. This control is accomplished in the main by the mores, by which society unconsciously controls itself very much in the same way that an individual is controlled by his subconscious urges, and by behavior which has been so thoroughly learned, as to be almost, or quite unconscious.

In so far as these fail, there must be conscious coercive control by society through organization, corresponding in the individual to the inhibitions of the unconscious by the fore-conscious.

Power subjects one to temptations; therefore, organization must:

Provide the means to bring to positions of power men of sufficient character; and

Provide the community the means to protect itself against break-down of character of the man in power; partly by fixing and enforcing responsibility.

In order that there may be foresight, organization must definitely provide for the exercise of the planning function.

Efficient planning can be based on nothing but knowledge, hence organization must provide for the acquisition and application of knowledge.

Organization is to society what the skeleton is to the body, at once the framework which supports it and the kinematic mechanism which shapes it to its immediate environment and which moves it. Organization must, therefore, possess sufficient flexibility to adapt society to its immediate environment and sufficient strength to move it.

When any type of organization has been tested by the above criteria, the matter of its success or failure may well be examined as a check.

Now that so many are clamoring about organization in this or that, when every state, industry and even religious faith must be maintained by organized cooperation, it may be pertinent to analyze the underlying or fundamental organization upon which every other depends, the family.

As we look back over the past, we are struck by the haphazard way in which the two oldest social organizations, the family and the state, have developed and endured through the ages by the mere trial and error method.

In the world of tomorrow, will such a method be adequate? We are learning, albeit bitterly, that though we live today, if we are to survive, tomorrow must be planned, and that in a more competitive world than yesterday's or today's. In order that we may avoid the mistakes of the past we must know its history as far back as possible.

Fairly advanced family organization can be observed even among the beasts. Several species have a very fair type of patriarchal family; for example, the old man kangaroo with his several wives and their progeny form a social unit for protection and possibly instruction of the young; but when the young males reach the mating age, they leave the family group.

The anthropoid apes have a family organization even more advanced. The higher types of anthropoids are apt to be monogamous. The naturalist, Hornaday, in his discussion of the various apes observed in the Central Park Zoological Gardens, New York, tells of a male ape who was faithful to the mate of his choice in spite of the utmost blandishments and modern leap-year love-making that a young ape flapper heaped upon him. In the wild state these animals group together in wandering bands, similar to the aborigines of Australia. There are enough families banded together to furnish males necessary for the protection of the young and the females. Without any definite leader the males understand the value of teamwork in facing danger. This is the highest type of organization among the beasts.

The original complete helplessness and long dependence of the human infant and the vulnerability of the human female, make it imperative that both mother and child should have assistance and protection, if they are to have a fair chance even of mere survival. In view of these facts it is remarkable that the most primitive and least regulative form of family which we can actually observe among men is probably less advanced than the monogamy of the higher apes. This low human form is monandry. In it a band of men and women live together. At any given time one man and one woman only are mates, but this pairing may not be, often is not, permanent.

Probably some more primitive and less regulative arrangement between the sexes preceded monandry, but what it was can only be conjectured.

It is evident that monandry is weak in the maintenance function of organization.

Society, in order to maintain itself must not only bring children into the world, but must rear and educate adequately for the responsibilities of adult life a number at least equal to the number of adults who die.

Mother love, under any method of regulation or non-regulation of sexes, will almost always cause women to devote themselves to their children. Father love is less certain. In fact a father's love of his child is often rather love of the offspring of a loved wife, of a being who seems to him to be part of a loved wife. When the father passes from mate to mate, this feeling must be very much weakened, if not entirely destroyed. In fact, under monandry, the paternity of the child must often be in doubt; and men do not love children of their wives by other men, step-children often excepted.

Therefore, the effect of monandry must be to put the burden of raising the children almost entirely upon the mother.

We, therefore, find it as the regular practice only in a few low grades of culture, mostly among the Australian aborigines, where infancy is relatively short, education almost non-existent; and the feeble communal interest of the men of the band in the boys is sufficient to train them for hunting and fishing.

In order for men to rise to any higher culture, a more effective discharge of the maintenance function of the family has been necessary, and men have been obliged to evolve better forms of family.

However, as there is always a temptation to give up those hard-won gains of the past, which can be held only by self-control against present inclination, civilized society tends continually to lapse into monandry by the path of quick and easy divorce.

It is easy to see that under stress of adverse circumstances, monandry or any other regulation of the sexes, tends to degenerate to polyandry.

Polyandry, which in unfertile regions is accepted in an endeavor to check the undue pressure of population on the means of subsistence, still exists in Tibet and among some Eskimos of the Aleutian islands. In a civilized community a group of impoverished men may combine to keep one girl, from which arrangement to the promiscuity of prostitution is only a step.

In any form, polyandry tends to produce sterility of the woman by over frequence of excitation, and, therefore, fails in the maintenance function of organization. For this reason, if there were no other, it is no better than an anti-social evasion of family responsibility, for the purpose of man's immediate gratification, regardless of the future.

What may have been the next forward step in the evolution of the family still exists among the jungle negroes of British Guiana. These people are descendants of slaves who escaped to the wilds, before they had become appreciably Europeanized. The climate and jungle made their recapture impossible. These blacks live in small jungle clearings almost completely isolated from civilization and even partially isolated from the neighboring black villages.

Among them the family is reckoned in the female line only. It consists of the oldest living ancestress and her descendants, both male and female, but in the female line only. A woman has her hut, which, with all its contents be-

longs to her. There she receives her husband as a guest. He does not belong to her family; but his children, both male and female, do. Thus sons are end products of the family, because their children belong elsewhere.

Naturally it falls to the men-folk of these communities to fare forth into the jungle for subsistence. Also the men are the only members of the community that are in any way in contact with other social groups. When knives and calico or whatever civilized products they deem indispensable to their existence are worn out, the men cut a mahogany tree and raft it out to a common center where certain trusted ones receive it, together with the orders for purchase, and transport it to market, negotiate its sale, make the purchases and return to the waiting jungle men. Thus civilization does not come into contact with the isolated blacks, and the female does not get any high-flown notions into her head.

As the boys grow into men they find their mothers less and less competent to protect them or to teach them the work and duties which fall to them. Therefore, in the absence of fathers, these functions are performed after a fashion by maternal uncles.

Under such circumstances, by the time a boy has reached adolescence, maternal control has weakened to what is due to affection; this may win deference, but is hardly likely to compel obedience. The family organization thus becomes weak and unauthoritative.

As there is no strong female control in the family, of course, there cannot be in the village. Each village is headed by a man, but his authority seems to be very far from despotic. The real government of the village is the "town meeting," which is attended by the women as well as the men. The men sit in an inner circle about the head man while the women form an outer circle. The latter's only part in the proceeding is an informal *viva voce* veto of any proposal that displeases them; but this veto seems always to be final.

These negro villages are probably typical of the matrilineal family, which has existed fairly commonly, and probably more generally in the remote past than at any time since, because when sexual relations were so unregulated as to leave paternity in doubt, fathers felt no responsibility for their offspring, and there could be no other kind of family.

It is evident that the defect of the matrilineal family as a social organization is its weakness. It can readily be imagined how poorly so loose an organization would endure the shock of war. Consequently it has persisted only in isolation. Apparently no higher organization has developed from it except through the intermediate step of the patrilineal family.

Nevertheless, the matrilineal family has some attractive features, notably a much higher status of woman than she usually attains among savages and its tendency to democracy. Under the necessity for a stronger organization in order to survive in a world periodically ravaged by war, pestilence and famine, most of mankind lost political liberty and woman sank into subjugation.

Possibly the evolution of the family may have been as follows: Besides isolation, the matrilineal family among the Guiana blacks has another favorable

factor. Nature is prodigal in the supply of their few and simple wants. Consequently they can live permanently in their villages; but most savages are not so fortunate. Living by hunting, fishing and by gathering what grows wild, they require immense areas to support them and only a few individuals can live together; or at most they can assemble only in winter or seasons when there are no roots, nuts or grain to be collected. When small groups are foraging or hunting abroad, their lives are in continual peril; and, as survival requires protection for the women and children, the more hazardous duties are performed by the men.

As constant dealing with the more difficult and dangerous problems of life made the men more competent managers, they gradually assumed all leadership; and the females became mere chattels. Hunting in competition with lions, tigers, bears and such animals made the men larger, stronger, more skillful fighters and more courageous than the women, so it is easy to understand how a little judicious connubial clubbing made the male master in family affairs.

Nevertheless tradition and custom were powerful and there are survivals that indicate that the change was slow and by means of an intermediate stage.

> "Our most characteristic example comes from India. The 'taravad' of the Nayars consists of a group of persons who trace their relationship to one another in a definite way. A characteristic group of this kind will consist of a man, his sisters, the children of these sisters, and the children of their daughter, but not the children of their sons."*

Here we have the matrilineal family still, but a man has become the head of it, already the traditional Old Man of the tribe.

Probably somewhere along here, men began to steal their wives. Undoubtedly it was inconvenient and often dangerous for a man to travel to his wife's family every time he desired her company. In the long run, how much safer and easier to lie in wait for an unwary female wandering outside her family camp, rap her over the head with a club, carry her off to his own mother's or uncle's hut and keep her there much the same as his other chattels.

Whatever primitive woman may have thought of this arrangement, primitive man evidently favored it and practiced it more and more, until marriage by capture or purchase became the recognized mode.

Among the higher animals the males sometimes fight, and to the death, but only in duels. Beasts of prey have crudely organized themselves for war on other species, but not on their own. Male wolf may fight male wolf, but wolf pack does not fight wolf pack.

It may readily be supposed that man's fighting evolved along similar lines.

There is evidently ample occasion for quarrels among primitive men. A hunting ground, a water hole, a prairie of wild barley, any of these things would be sufficient *causus belli*.

We may imagine that at first such questions were settled by the rival Old Men in single combat; but man was slowly organizing, not only the family,

*Rivers, Social Organization, p. 15.

but everything else and, among other things, fighting. Organized fighting was—War.

Attack brought on reprisal and reprisals produced feuds, and war became the normal condition of human life.

Then indeed the male became dominant. Behind his militant form the female crouched for safety. His alone were the discipline, the organizing ability and the initiative due to war. Thus war both confirmed the male's dominance and made him fitter for it. Also, decked in war paint and feathers, he was no longer the mere hunter, but the warrior, the brave—to the woman, her hero.

Now the Old Man could no longer drive away the young men because of their gallantries with the women. He must keep them with him, or be conquered by some other Old Man with more fighting sons. Daughters might be married off into other tribes, but sons' wives must come into his tribe that their sons might be his warriors.

Thus, almost universally, the matrilineal family disappeared and the patrilineal family took its place.

The boys from their mother's arms were taught fear of the Old Man and obedience to his will. Such obedience became a habit; and, when experience had taught him wisdom, but age had lessened his physical prowess, the family continued to obey him from force of habit.

A leader trained and successful in hunting and in savage warfare could not be other than skillful in judging conditions and quick and accurate in adapting his conduct to them.

It is evident that the father-family excels every form that had gone before it in producing a leader who was at least relatively fit and in giving him power, in causing his family automatically to obey him. Also, while the father-family depends almost entirey on the personality of the father for planning for the distant future and has in it only the germs of progress; under primitive conditions it assured planning for the immediate future and adaptability to existing conditions.

These qualities have caused the father-family to survive for many thousand years, and it is still the usual type; but they do not make it the ultimate type; and, in this country at least, we are working out another type, the bi-lineal, or father-mother-family.

The stress of daily life made it necessary for the males to band together. In hunting or foraging they had to depend on concerted action much like a pack of wolves, who together drag down prey which one or two could only observe and desire. The female's work did not force group action, and she became more of an individualist, and from this circumstance she was later to suffer. Lack of cooperation held woman in bondage through centuries. In fact only in recent years are they enjoying the benefits of cooperation that the men have had since early cave days.

Woman's position was further lowered through capture and purchase. As she could be bought or sold like any other livestock, she was so classified in

her father's and brother's estimation and, as a consequence, lost the ability to help herself.

The capturing and enslaving of the women and children of vanquished foes were practiced from earliest antiquity. The females served the victors as concubines as well as slaves. In this concubinage we may see the seeds of polygyny, one might say the very lowest type of it and its earliest example.

Polygyny has been a social arrangement forced by the strong on the weak. To have several wives, may under some circumstances seem a good arrangement to the husband; but that it should be likewise agreeable to the individual wives seems doubtful, although in the days when wives were the only laborers, additional hands lightened the load and may have been welcomed.

Having more than one wife was, of course, the result of man's desiring more than one. This desire may arise from sexual motives alone, as primitive society through the taboo otherwise requires of him long periods of continence; female youth and beauty exercise great attraction on savage as well as on civilized man, and the slavish working women of hot climates soon fade; then also there is man's taste for variety. Also man's desire or need of offspring may have led to his taking more than one wife. If his wife was barren or gave birth to female progeny only, he took additional wives to secure male heirs. Maybe he desired a large number of children so as to entrench his economic position, authority and importance in society. It was from such motives as these that the Patriarch came to be. His was a position of authority and security, but his type of family was larger and more complicated than that of early polygyny.

In the beginning of polygyny each wife probably had her own hut where she and her offspring lived, making a collection of huts as one household with one sire over all. Economically the household was probably well situated, as there was a division of labor, and the founding of such a family presupposes a man of some wealth and force of character.

The father designated one of his sons to be his heir. This might be the eldest, or son of his first or head wife or son of a favorite wife. This choosing of an heir became a fertile field of discord in his collection of wives, for however the wives liked or tolerated one another, no mother could see her son supplanted or overlooked with equanimity. Jealously and intrigue, to say nothing of hatred and envy, do not make for harmonious companionship.

Two women receiving and desiring the conjugal affection of one man must of necessity be rivals, whether their positions are on a par or not. Much more the scheming and hatred if one holds a position inferior to the other; and a mother's love for her children, and desire for their welfare must drive her to any ends to secure advantages for them. Man's love or passion is not capable of equi-partition, and at a given time there is bound to be one among his wives who is his favorite, and who as such holds position and rights above the others.

We see that monygyny, the supremacy of one wife with other lesser ones, is the real condition of most so-called polygynous households. Sometimes it is

the first wife married, or the one of highest social position or the mother of the first born who is the principal wife. She is sometimes called the "great wife" and the others the "little ones." The head wife is the mistress of the household and the lesser ones are practically her handmaids. There is a correspondingly great difference among them in treatment of the children of the head wife and the subsequent ones. With the admisssion of decided favorites we can see the deleterious effects on the children of the several wives.

Jealously among the wives is inevitable, and many are the tales of the fields of battle, previously peaceful households have become, upon the arrival of a new wife. Even after she has fought for her position and won it, there is bound to be much discord and enmity. A most striking example of the extent of this female jealously is the frequent absence of noses among the women of Fiji, which lack was explained to the inquiring missionary thus: "It is due to the plurality of wives; jealousy causes hatred, and then the stronger tries to cut or bite off the nose of the one she hates."

From an organization torn by strife and dissention we cannot expect much in the way of maintenance, and so we do not find polygyny an enduring institution in progressive civilization. Under unusual circumstances it has had an important rôle; for example, when many of the males were killed in battle and the population was cut down, the only way to build it up again rapidly was for each of the available men to mate with a number of women.

The patriarchal family may be considered as the type of family carrying to their ultimate development many of the ideas underlying the polygynous union; but not all patriarchal families are polygynous, nor were the earliest ones.

The Hebrew patriarchal family was polygynous while the Greek and Roman patriarchal families were not. The first existed without any state organization and was thus all the more important as a small political unit sufficient unto itself. In the two latter cases the patriarchal family was very important though included in a highly developed state.

This type of family confers more authority on one person than any other we have thus far considered. The head in the person of the patriarch collects unto himself a large assemblage of relatives, blood and adopted, and sets about to govern and provide for them. The patriarch is revered, is usually the religious head of the group, and hence has great authority over the various members of his household.

Such a family is very important to a nomadic or pastoral people. By the very nature of their life the head of the group must move with his people over a wide, sparsely settled territory, the group must be held together by some very real interest, which the patriarchal family furnishes in its common tie of blood relationship or adoption, which has almost as strong binding power. The group is economically independent, though the separate members are interdependent. The patriarch owns all the herds and material wealth of the group but they all receive a living from it, and in turn contribute their bit by handicraft and in tending the herds and flocks, which could not be maintained without their help.

In case of the death of the patriarch his holdings *in toto* pass to the eldest son, or to some other male heir, so that the same type of organization persists.

In some countries in remote times the patriarch had absolute authority over his household, even to life and death. The Spartan father could expose the weakling on the mountains, and the Roman father could slay with his own hand a child that dared rebel against his authority.

Here we have centralization in the extreme, a small scale government by an autocrat; and like all autocratic governments, it varied from the very best to the very worst, dependent upon the character of the patriarch. This father-ruler was more apt than not, to be vitally interested in the welfare of his sons, as they in turn were in their children.

The patriarchal family has endured to a greater or less degree since time immemorial. In the days of Abraham it was an institution of universal extent among the Hebrews; then down through the ages, in Greece and Rome, through the middle ages, and on to the English patriarchal family, until at the present day we find it most completely worked out in India.

The later patriarchal groups were sometimes of much political power and great wealth. They were the foundation stones of powerful states; from their political union grew kingdoms and empires.

At the head of such a family there was a powerful individual who exercised exclusive control, he came to his position by right of superior years and often times primogeniture, but not as an untaught or untried incumbent of the office, because from the time his grandfather had the patriarchal power he was marked out as the heir presumptive. Hence, though leadership did not go to one selected on account of his ability, the head, set apart from early years, was bound to be capable to some degree.

His power was absolute, and was apt to be directed so as to bring the greatest good to the greatest number. His welfare and that of those nearest and dearest to him was wholly contingent upon the quality of his administration. All selfish motives needs must be concerned with those included in the family group so there was removed most of the danger which is inherent in rule by one man; that is, power wielded to contribute to his own dignity and position regardless of the effect upon subject individuals.

The patriarch's ideals and hopes must be the same as those of his children and his children's children, held together as they were by bonds of affection and mutual help. So there was cooperation with an experienced and interested director.

The patriarchal organization, as it was entirely dependent for its welfare upon the patriarch, gave rise to an extraordinary reverence for him and for the elders in general.

The Biblical injunction "Honor thy father and thy mother" is about the mildest form of this. At the other extreme it leads to the investiture of the patriarch with a sort of quasi-divinity, at least to making him the high-priest of the family, during his life and to the worship of him as an ancestor, or even as a demi-god, after his death.

In so far as this form of control was insufficient, the disciplinary, coercive control of the patriarch was very complete. In general the harshness of ancient life was toned down among the Hebrews by the superiority of their religion, although religious belief itself led Abraham to offer his son as a sacrifice. It did not withhold Jephthah from vowing to offer the first living creature that should welcome his return: which alas! was his own loved daughter; and though it became a custom for the daughters of Israel to spend four days each year in lamentation for Jephthah's daughter, no one questioned the father's right to make such sacrifices.

Roman history gives frequent allusion to the father's absolute power over the lives of his progeny, and to his too frequent use of that power.

With the elements of strength above noted, when a patriarchal family had the good fortune to be ruled by men of ability for several generations in succession, it tended to grow and grow. In fact it contained within itself the germ of the autocratic state; and that it did at times actually grow into the latter is shown, for example, in the case of the Hebrews, whose primitive patriarchal family of Abraham, Isaac, and Jacob, grew, through hundreds of years and through many vicissitudes, into the autocratic state of David and Solomon.

At this point the patriarchal family has outgrown its possibilities and its former strength becomes its weakness. To David, peasant born and self-made, Israel might be a family of which he was the father; but to Solomon, harem-born and palace-reared, it was an estate to be exploited, and his oppressive rule started the downfall of the Hebrew state, as the similar rule of Louis XIV started the downfall of the French autocracy. As Victor Hugo remarks, the fundamental weakness of autocracy is that the autocrat, though he may call himself the "Father of his people," cannot really be such.

To guard against the continuance in power of one incapacitated by age, it was usually the case that, with the coming of a greatgrandchild, the power passed to the chosen son of the patriarch, usually the eldest, though sometimes the patriarch selected some other son to succeed him.

Aside from such protection against senility of the patriarch, this organization failed altogether in the function of protecting the family against breakdown of character or ability of the ruler. This weakness became critical, as soon as the family had grown to the point where the consciousness, on the part of the patriarch, of the paternal relation and responsibility, had become materially weakened.

At this point also, patriarchal organization became unwieldy. The patriarch was not only father, but also king, highpriest, military commander, business manager, judge and minister of education. Only in a very small organization could these multiple and varied functions be efficiently performed by one man. Hence arose the necessity for delegation of functions to subordinates. History shows that such delegation was often reluctantly and insufficiently made, and that it was still more often very injudicious. Hence, even with an able and

good patriarch, patriarchate on a large scale was apt to fail even in the function of bringing to positions of power, men of sufficient character and ability.

It was under the patriarchral organization that mankind as a whole passed from the nomadic existence to that of sustained agriculture, and it is herein that we see its adaptability to the environment in which it developed. In fact, it is difficult to imagine how the race could have survived, under the increased demand of its larger numbers for subsistence, if this adjustment in organization had not been made.

> "So rapidly did population multiply under its improved conditions that the new type of civilization took possession of the habitable earth and established itself so firmly that even now the larger part of mankind lives in a patriarchal, agricultural civilization."*

Viewed as a whole, this patriarchal form of family seemed to accomplish all that was required of it in bringing the nomadic peoples through their shifting, transitory life into the more serene but sterner, more exacting, agricultural stage. It has been a winning organization, as evidenced by its continued existence up to the present day among people at that stage of economic progress.

The most glaring defect of the whole system was the subjection of woman. As the term "patriarch" implies, it was a system in which the male predominated in everything. Woman was wife, slave, odalisque or drudge, depending on the wealth and disposition of the patriarch, but always property, whether under monogynous or polygnous marriage; and classed with the children, she merely aided the master in working out his destiny in a man-made world. In this respect we see the temptation to which man, the powerful one was subjected; he yielded to it, claiming for himself domination, leading to utter disregard of woman and very great cruelty to her.

History abundantly shows that no class of society can be permanently oppressed without danger to society as a whole. While woman, with her natural masochistic complex, reacts less vigorously against oppression, than probably any other member of society, even she cannot with impunity be permanently oppressed.

Under the relatively stable condition of the patriarchal family, we find the beginning of acquisition and accumulation of knowledge. Unfortunately, under the exaggerated reverence for the elders which naturally accompanied this type of organization, men came to think of wisdom as being entirely in the past. This backward way of looking in a forward moving world does not make for progress. In China and India where for generations, education meant learning by memory the sayings and the history of the ancestors, we can see the stupefying effect of looking backward. The dead hand of the past lies heavily upon the patriarchal family. It is rigid and immovable in the iron mold of tradition. Hence its gradual extinction in the progressive civilization of the occident.

As cities grew and men began to earn their living by various crafts, they found themselves independent of the patriarch and would no longer submit to

* Dealey, The Family in its Sociological Aspect.

his authority. At the same time associations, such as guilds, trade unions, benevolent and fraternal orders, business and professional societies sprang up, to which a man looked for protective, collective action and comradeship, for which he had formerly depended on the family. Also it was difficult, nearly impossible, for a large patriarchal family to live together in any city. Gradually the city or city-state and after that, the larger state, inspired the feeling of idealistic devotion which formerly had attached itself exclusively to the family.

However, while the patriarchal, polygynous family disappeared from the cities, the single polygynous family consisting of a man, his wives, and their children; that is, of two generations persisted, and still persists, probably among a majority of the human race as a recognized, lawful and respectable institution, though, from economic necessity, it probably is not the practice of the majority of men. On the other hand polygyny long ago vanished from occidental civilization, except as a surreptitious and disreputable practice.

The causes which produced polygyny have been discussed above. Therefore, it remains at this point only to inquire into the causes of its disappearance, as a reputable institution from the highest civilization which the world has yet produced.

As one of the main causes which produced polygyny was economic necessity, so it was also the chief reason for its disappearance. As woman's horizon began to extend beyond the four walls of her home, she grew discontented at being merely property and began to demand a better status, and from being an unpaid laborer, she took not only the products of her own labor but demanded a share of the family income. Also, as medical science developed and infant mortality decreased, it did not need so many human incubators to produce the desired number of offspring. As an economic example the following is typical. In a certain factory the writer's attention was drawn to a piece worker, because he never reported for work until well along in the afternoon. Having occasion to visit the factory at night, the writer was surprised to find this man as night foreman of a department, and later was more surprised to learn that, in his spare time, he was running a poultry farm in a suburb. Naturally the writer was interested in such surpassing industry and learned that this man had a divorced wife with a family of children to whom he was paying alimony, and a present wife and family of children whom he was supporting. This illustrates what polygyny means at present in occidental civilization. No wonder it died out. It was impossible.

In our civilization polygynous relations mean either no children, or that the burden of supporting them will be thrown very largely upon the mother. She is at best inferior to the man in earning power, and bearing children makes big demands on her time and strength. The result is inability to give the children proper care, to bring them up rightly, and to educate them adequately. In any case polygyny falls, under the stress of our civilization, in the maintenance function of organization, either by not providing children, or by not preparing them adequately for their part in our complex civilization. If our civilization did not kill polygyny, it would kill our civilization.

It is probable that, in the evolution of the race, every possible form of relation between the sexes has been tried. The objection may be offered that in the above discussion, there is no mention, as any other than an illicit and disreputable relation, of that promiscuity which is so warmly advocated by some writers of today.

Lower animals are promiscuous; but scientists tell us that apes are not; while, as has been stated, monandry is the least regulative form of family actually observable among men. Hence the probability is that promiscuity was tried out and abandoned before our ancestors became human, or even anthropoid.

Out of all this welter of racial experience has emerged permanent, exclusive, pair marriage, monogamy, as the ideal and only recognized, lawful and respectable form of family, in our occidental civilization.

As we today think of the family it means a small group, father, mother and the children born to them. Of course, in the family there may be the grandmother or aunts or other relatives and servants, but the family in which modern western civilization has its roots consists of these few blood relatives of two generations. It is for their needs that present-day institutions exists and whether they be religious, educational, political or for general welfare, they all presuppose this basic institution, the family, of which the primary purpose is the rearing of children.

People seem to forget this primary purpose of the family. In order to maintain our complex civilization, children in sufficient numbers must be cared for through a long infancy, must be taught the skill necessary to enable them to create their share of the world's production, must be thoroughly grounded in the morality necessary to the welfare of society and must be inspired with ideals which will cause them to practice this morality.

If this maintenance function of the family were generally neglected, persons now of middle age, if they were to live out a very ordinary duration of life, would spend their old age in an anarchic and impoverished society, as indeed they seem likely to do, largely because of general neglect of this function of the family during the last generation or two. For their own welfare men and women must fulfill this maintenance function. To do so probably will entail sacrifices, but they are part of the price which must be paid for the privilege of living in a highly civilized society. Unless the family effectively performs this maintenance function, our civilization must perish.

From what has gone before it is evident that permanent, exclusive, pair marriage is the only basis thus far evolved for a family which can adequately perform this vital function.

In the monogamous family woman's position has improved. Her part in the rearing of children is much more important than that of the father; and, as children are the reason for the existence of the monogamous household, woman, as the chief factor of their welfare, has advanced a step in self-realization.

In the United States at least, this improvement in the status of women has practically put an end to the father-family and has put in its place the father-mother-family with the man and his wife in joint control and with the division

of authority between them dependent on personality, ability and inclination rather than on sex.

While this dual control is in the interest of justice, it, as any division of authority always does, seriously threatens stability. At the same time the stability and permanence of the family is seriously threatened from other causes. Under these multiple stresses it shows grave weakness, and many are seriously alarmed about it.

Without joining the alarmists, the writer wishes to point out that the present occidental civilization has only three choices:

To go out of existence;

To find some adequate substitute for, or improvement on the monogamous family; or

To maintain permanent, exclusive pair marriage. As for substitutes and improvements, many are suggested; but, upon critical examination, they turn out to aim at relief of individuals from the sacrifices necessary to maintain the monogamous family, with little or no regard for the welfare of society. The only one which contains anything which has not already been tried out and discarded, is Judge Lindsay's suggestion of companionate marriage. It is sufficiently condemned by the fact that continued practice of contraconception during the early years of marriage, which it contemplates, tends to sterility and therefore gravely impairs the maintenance function of the family.

The Russian experiment of confiding the care of the children to the state, while the parents pursue independent careers, seems rational, if we leave out of consideration the need of the child for love—demonstrative love. The institution may take good physical care of the child, better care than the home could; but it cannot love him, without which love and understanding the finer mental achievements of the child are not attained.

As to the maintenance of permanent, exclusive pair marriage, the difficulty due to postponement of marriage to too late an age, will probably be met by the general practice of efficient management. Already in the United States this has enabled us to produce more than, in this period of business depression, we are able to consume; and it remains only to bring distribution to an efficiency equal to that already attained by production, to increase the national well-being to such a state, that marriage at a sufficiently early age will be possible to all who are fit for it.

The withdrawal of women from the home by opening to them careers outside of it, is a far more serious threat. In a few generations, nature may take care of this in two ways. The woman who prefers a career to a home does not transmit her characteristics to posterity, and may become extinct. The more vigorous and healthy life of girls today than women have had for many generations, is making them better female animals and consequently more desirous of mates and offspring.

However, the writer is greatly interested, in this connection, in the case of a woman friend which shows what can be done by intelligence and good-will. She is a highly educated woman who married a professional man. She joined him in his practice and contributed largely to their joint success. In so doing

she made for herself an international professional reputation. Meanwhile she has borne eleven children of whom ten are living. While she is a loving and efficient mother, she has not burdened herself with household duties. Capable, paid assistants have relieved her of those things. If a woman can earn outside the home and wishes to do so, why should she not, and employ others of more domestic inclinations to relieve her of household minutiæ?

To the present time this woman's career would hardly be possible except in working, as she did, with her husband. Absence from work every year or so, for months at a time, in anticipation of childbirth, would have ended her employment under any other condition.

Here there is need of social adjustment. We have got over our prudery with amazing speed in recent years. Why not take another step? Why should a pregnant woman hide herself for months, as if she were ashamed of what is, in truth, her greatest glory?

In so far as the monogamous family fails, it seems to the writer that the defect is not in organization. This can deal only with externals, while the difficulties in marriage arise from the intimate conjugal relations of the man and woman. No organization can reach them; but remedies may be found in the application of the other principles of management, especially Ideals, Instruction, Fair Deal and Discipline.

AWARDS OF SIGMA XI GRANTS-IN-AID FOR 1934-1935

The following grants-in-aid have been awarded for 1934-35 by the committee in charge of the distribution of the society's fund for research:

Prof. H. R. DeSilva, Massachusetts State College, $100, for a study of the correlation of body voltage changes with basal metabolism by gasometric method.

Prof. Rachel Emilie Hoffstadt, University of Washington, $100 (renewal), to continue a study of the relation of the soluble specific carbohydrate of staphylococcus aureus with its variants.

Prof. I. M. Kolthoff, University of Minnesota, $300, for a study of the internal structural changes taking place in freshly formed lead sulfate.

Dr. F. C. Schmidt, Union College, $150, for apparatus and chemicals for continuance of measurements of heats of reaction in liquid ammonia.

Prof. T. L. Smith, College of the Ozarks, $150 (renewal), to continue a study of the effects of x-rays and radium emanations in producing genic changes in Galleria.

Prof. W. J. Luyten, University of Minnesota, $200, in support of studies of proper motion of faint stars.

W. R. Whitney,
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